Ukrainian subterranean warfare tactics and possible new anti-missile technology using the same technology of self-driving cars.

At the moment, there is a strong channel of money and arms supply to Ukrainian forces, but it should be made clear that as this conflict drags on, Ukrainian forces may be forced to use tactics akin to the ones used by those who share similar goals. It is very likely that the Ukrainian strategy could find itself strongly aligned with strategies used by Mideast insurgent groups like ISIS and Hamas, whose backdrop involves contention with a military force much larger than their own. Much of ISIS's leadership is comprised of Saddam loyalists who refuse to accept the overthrow of their longstanding leader. Furthermore, as far as the Ukrainian counteroffensive goes, there is no way to stop what has been set in motion by the Russian invasion—the prospect that Russians and Ukrainians are now enemies to the very core. Now that Ukrainians and Russians have become adapted to the idea of warfare and death, many will have no qualms about pursuing this reality for years to come. It is no different than Hamas or ISIS, as both of these entities have settled on the reality of war and death and insist on maintaining this for an indefinite period of time.

There is one thing that the Ukrainian insurgency will provide to the world. Further advances and knowledge in subterranean warfare and anti-missile defense, which will be a likely strategy that Ukrainian insurgents may apply against the Russian occupation, seeing that the only method of warfare used by major powers to stop insurgency, in most cases to no avail, has been airstrikes. This has been the case throughout modern history.

Ukraine demonstrated the effectiveness of secret underground tunnels when they put up a fierce intransigence amid the Russian assault on Mariupol during the Ukraine/Russia war of 2022. In mid-April of that year at the steel factory called Azovstal Iron and Steel Works located in Mariupol, Ukrainian defense forces took refuge there and conducted an extraordinary resistance to Russian forces. The factory was fortified with steel and underground tunnels, making it hard for Russian airstrikes to accurately locate and destroy Ukrainian forces. When Russian troops made their way further into Mariupol and surrounded the factory, Ukrainian forces, because of the fortification that the underground shelter provided, remained adamant to fight till the last man. Back in February at the start of the invasion of Ukraine, Russia launched an amphibious assault on Mariupol and shelled it relentlessly, killing 10 Greek civilians and a 6 year old girl. Back in 2015, a series of Russian airstrikes had killed 29 civilians in Mariupol. By the end of February/early March, Mariupol, though still under Ukrainian control, was completely surrounded by Russian forces whose shelling of the city cut off access to water, internet, and electricity. This stoppage of vital resources was the only means of stopping the Ukrainian resistance. Many who were killed in Mariupol were not sheltered in subterranean bunkers. On March 2nd, as the Russians were preventing civilians from evacuating the city, hundreds of civilians were killed after a residential area was shelled relentlessly by Russian forces. The next day, the shelling continued as the DPR urged Ukrainian fighters to surrender or face guided artillery strikes. The Russian Ministry of Defense reported that the Russian troops seized more areas nearby. Meanwhile, the supplies in

Mariupol were gradually running low, and calls were made for reinforcements and the evacuation of civilians as the Russian forces were shelling critical lifelines such as hospitals. Had the underground fortifications at the Azovstal factory contained a secret tunnel long enough to reach Ukrainian controlled areas, a supply line could have been established that would have allowed civilians to escape and also provided Ukrainian troops hunkered down in the bunker with vital reinforcements to continue resisting the Russian onslaught. A ceasefire had been subsequently enacted so that the 200,000 civilians trapped in Mariupol could evacuate, but this was because the Red Cross got involved as a facilitator and promised to ensure the establishment of ceasefire agreements which would enable civilians to exit the city. An extensive secret underground network capable of reaching multiple areas of Ukraine would have allowed civilians to escape regardless of Russia's operations. Anyhow, when the negotiated ceasefire was finally in place, civilians were only briefly allowed to vacate Mariupol and seek refuge in the city of Zaporizhzhia. Reason being, is because the Russian forces commenced shelling the city which forced civilians to turn back and stay put. Russia's understanding of the ceasefire was that civilians would be allowed to leave, but through a corridor towards Russia, not towards Zaporizhzhia. Ukraine, however, feared that Russia would send Ukrainian civilians held captive to secret concentration camps either in Russia or separatist held areas. This first attempt on March 5th at establishing humanitarian corridors only resulted in 17 people evacuating. The second try the next day was once again subverted by Russian artillery strikes which destroyed the city's fuel pipeline and access to heat in much of the city, resulting in 700,000 people ending up without heat and subsequently in danger of freezing to death in temperatures that had gone below zero. The last remaining communication line, a cellular tower, was damaged by Russian shelling. The Red Cross said that the new ceasefire was in principle only and that much of the other circumstances surrounding how civilians would evacuate remained vague. One of the roads that was going to be used to evacuate civilians was mined. And on March 8th, Russian forces shelled one of the evacuation routes as civilians were being evacuated. Large numbers of civilians were killed in Mariupol and many were buried in mass graves. Even as this was taking place, Russia managed to shell the gravesites where many victims were being buried. An attempt at another ceasefire was stifled on March 9th, when Russian forces began shooting at construction workers and checkpoints established for evacuation. This was followed by an airstrike on a maternity ward and hospital where three civilians were killed and 17 wounded. Three days later, as Russian troops captured the eastern parts of Mariupol, roughly 82 ethnic Greeks were able to get out of Mariupol through one of the corridors established. This was followed by more artillery bombardments of Mariupol by Russian forces. Vadym Boychenko, the mayor of Mariupol, said that on March 13th, the Russian military unleashed hundreds of bombs in a 24 hour period as food and water had become extremely scarce. The Ukrainian forces were, nonetheless, able to provide some resistance and destroy a number of Russian military vehicles as well as kill 150 Russian troops

fighting in the city. Meanwhile, ethnic Turks were on standby waiting to be rescued and evacuated by the Turkish government. On March 14th, a convoy of evacuees were allowed to evacuate Mariupol, and the Russian Defense Ministry confirmed that aid was being supplied to the city. The next day on March 15th, even more civilians were able to leave, roughly 20,000. On March 16th, however, a theater in Mariupol where hundreds of civilians had taken refuge was hit by a Russian airstrike. It was reported that 600 people were killed as a result. This number turned to be an exaggeration. But moreover, the underground basement at the theater allowed scores of people to survive the airstrike there. This gives credence to the effectiveness of underground structures providing the highest level of effectiveness in evading airstrikes. After the attack, over 100 of the people inside hiding in the basement survived and emerged from the theater debris on March 17th. In fact, Ukrainian officials initially reported that there was no one killed during the strike.

The assault continued when 2 days later the DPR forces seized the Mariupol airport, driving out the Ukrainian forces. When the DPR advanced, shortly thereafter, into the center of Mariupol, clashes between them and the Ukrainian forces took place at the Azovstal Steel plant. During this time, allegations that Russia was deporting civilians to camps and remote areas of Russia began circulating. After Russia denied that such allegation were true, another school was bombed in Mariupol, a school that was being used by 400 civilians to shelter themselves from the shelling taking place in the city. In the meantime, the Russian forces continued to demand that Ukraine surrender. However Ukrainian forces continued to refuse. On March 21st, Russia responded with a barrage of airstrikes which led the mayor and other city officials to flee shortly after. The Russians at this point were going around the center of Mariupol declaring victory as Russian troops advanced deeper into the city. On March 27th, the mayor called for an immediate evacuation of the remaining residents in Mariupol as food and water had been totally depleted to the point that even Ukrainian soldiers had nothing to consume. Despite such deprivation, Ukrainian soldiers insisted on fighting to the last man, leaving neither civilian nor soldier behind. The next day, the mayor admitted that Mariupol was under Russian control and that 5000 people had perished during the siege. Ukraine reported that 20000-30000 had been captured by Russian forces and sent to camps located in Russia. That same day, the Russians occupied the military headquarters, administrative building, as well as the headquarters of the Azov regiment. The Russians, throughout the conflict, had altogether shot down 90% of the rescue helicopters sent by Ukrainian President Zelenskyy to conduct evacuations as well as resupply the Azov soldiers taking cover at the Azovstal Steel plant. The Ukrainian military had no choice but to eventually splinter into multiple cells after the Russians captured 267 marines from the 503rd Battalion of the Ukrainian Naval Forces on April 4th. This caused a rift among Ukrainian fighters from the Azov regiment and the 36th Separate Marine Brigade, whose lines of communication had been broken by the surrender of the 267 marines of the 503rd Battalion of Ukraine's Naval forces. Ukraine, in response, attempted

to resupply the Azov fighters stationed in the Azovstal steel factory, but the deliveries could not be made due to Russian fighters shooting down the MI-8s used for the mission. After the Russians captured the bridge leading to the Azovstal steel factory, they were able to take control of the fishing port and cut the line of access between the Ukrainian soldiers at the fishing port and those at the steel factory. Had there been an underground route to the Ukrainian forces at the fishing port, things wuld have been different. Russia cutting off access by destroying the bridge was a major blow that coincided with a severe shortage of ammo that limited the amount of resistance that the Ukrainian troops holding out at the factory could apply against incoming Russian soldiers. At this juncture, it was easy to forecast that Mariupol would, within a short time, fall into the hands of the DPR and Russian forces. A number of Ukrainian troops from the pocket of Ukrainian soldiers from the 36th Separate Marine Brigade held up at the llich steel plant were taken captive on April 11th. Some of them managed to escape and join with the Azov regiment at the Azovstal steel plant, while others were killed en route. The leader, Baranyuk, was captured by Russian forces as he tried to flee the city rather than link up with the Azov. The remaining 1,026 Ukrainian fighters at the llich steel plant surrendered the next day, which left Mariupol to be defended by two small pockets of Ukrainian soldiers. Unsurprisingly, the Azov leadership was disappointed with Baranyuk because he did not relay the plan to escape the llich steel plant with other military personnel, nor try to link up with the Azov regiment as others who escaped the plant would try to do. Instead, he, as llia Samoilenko would express, tried to flee "taking with him people, tanks and ammunition." Subsequently, Ukrainian fighters surrounded by Russian forces at the Azovstal plant requested reinforcement and more supplies, informing the Ukrainian command that the situation was dire, but that fighting was still possible.. The steel plant was a strong fortification and there were many underground tunnels that allowed people there to take cover and remain safe from air strikes by Russian forces. It also provided stealth to Ukrainian troops which made it even harder for enemy forces to locate them. However, without a supply line, there was no way for Ukrainian forces to fend off continuous Russian strikes because ammunition, food, and water would eventually run out and leave those sheltered there with no choice but to either surrender or die from destitution.

After a port was captured near Mariupol's beach, some of the Azov fighters from the Azovstal plant rescued and evacuated the 500 Ukrainian troops and police surrounded at the port. According to an officer of the Ukrainian Marines, the Azov breached the port and provided cover fire for the Ukrainian troops stuck at the port, allowing them to escape. This left those Azov regiment and other Ukrainian fighters at the Azovstal steel plant as the last remaining pocket of Ukrainian soldiers resisting the Russian advance. Yet, they refused to surrender amid Russia's threats to annihilate them. The remaining number of Ukrainian fighters were estimated to be around 2900, according to Russian officials. Even in light of the Russian control over the city, the Russian troops had not yet been ordered to raid the Azovstal plant. It was believed by the Kremlin

that Ukrainian forces would surrender once they ran out of critical supplies. But Ukrainian officials took it to mean that Russia was admitting that they had no ability to infiltrate the complex infrastructure of the plant. The subterranean aspects of the steel plant was akin to the methods used by ISIS and Hamas to successfully evade airstrikes in the middle east. However, Russia's main goal in Mariupol was connecting the city to Crimea so that water and other supplies could flow there. Once this goal was reached, Russia felt no rush to take control of the steel plant, figuring that an all-out assault there would needlessly waste military personnel and be extremely costly.

On April 22nd, Russian troops began expanding their presence outside the Azovstal steel plant very close to the positions of Ukrainian soldiers in Azovstal. It was confirmed that day that the only remaining Ukrainian forces in Mariupol were those hiding out in the steel plant. Subsequently, Russia began pulling some of its troops out of Mariupol and reassigning them to other parts of eastern Ukraine. This was followed by a barrage of airstrikes on the Azovstal facility by Russian forces, one of them striking a military field hospital, wounding hundreds more. Just after this on April 30th, a humanitarian corridor was established which was brokered by Antonio Guterres when he visited Moscow the week before. Gradually at the start of May, civilians hiding in the Azovstal facility were being allowed to leave. 100 left Mariupol on May 2nd, while Russia pulled many of its forces out of the city and redeployed them elsewhere in the Donbas region. This was confirmed by the US Department of Defense. Folowing the pull-out, Russia's offensive in Mariupol had become strictly airstrikes. The following day on May 3rd, however, the Russians attempted to breach the plant through the tunnel system after they had been tipped off on the location of the underground network by an electrician in what was an act of treachery on his part. Two days later, more civilians had been evacuated from the Azovstal facility through a humanitarian corridor designated to operate between 8am and 6pm.

The Russians in a final ploy to get Ukrainian troops at the Azovstal facility to surrender, used thermobaric bombs on Ukrainian soldiers. After a long standoff by the Azov regiment and other Ukrainian fighters, President Zelenskyy would give the order for Ukrainian forces in Mariupol to surrender. This comes after he vowed not to cede any territory to Russian forces. Subsequently, the remaining civilians would be completely evacuated by May 7th. The remaining soldiers who came out to negotiate surrender were taken captive by Russian soldiers who would evacuate them from the plant, treat those who were wounded, and detain them along with the remaining Ukrainian soldiers at an area controlled by the DPR forces. The Ukrainian command confirmed that the battle was over and Mariupol was now in the hands of the DPR and Russian forces. The last remaining Ukrainian soldiers surrendered to the Russians on May 20th. The Russian president Vladimir Putin promised to treat the prisoners of war according to international standards. However, some in the Russian government were against allowing members of the Azov regiment to be released in the case of future prisoner swaps. Ukrainian resistance using the underground

fortifications at the Azovstal plant was a good example of just how effective tunnels are at combating airstrikes.

Throughout the history of warfare, subterranean structures have been used against enemy forces with great success. Back during the Arab invasions in the 7th century, monks found that they could successfully evade Arab forces by hiding underground. Back in WWII, the Japanese were effective in building underground fortification against US air power, and so were the Chinese, who built underground fortifications against Japanese air power. The Vietnamese during the Vietnam war was possibly the best example of how effective underground fortifications are against a superior air force. Many of the larger military powers, have had no formidable answer for this type of defense, even against small pockets of militants. The current conflict in the Middle East(2001-2022 as of now) is marred by the continued survival of these insurgent militant groups. Major military powers like Russia and the United States have carried out a number of aerial attacks against them in recent years, but only with enough success to weaken the threat, not totally eliminate it. In recent years, Israel has faced numerous problems with the underground operations of Hamas, the militant group that controls the Gaza strip. Not only for smuggling resources into Gaza, the tunnels used by Hamas has allowed them to, at one point, ambush and kidnap an Israei soldier from Israeli territory. Hamas is also able to conceal rocket fire locations with the use of the tunnels, making it more difficult for Israel to locate and destroy them. This underground methodology is also how ISIS, the Al Qaeda offshoot terror organization comprised of Saddam loyalists, continues to launch ambush attacks against Syrian regime soldiers, even after years of being bombarded by both US and Russian airstrikes. The operations of Hamas and ISIS and their continued survival in small numbers is setting the stage for a new type of warfare: Subterranean warfare. This will be further pursued in Ukraine as insurgents there look to resist the Russian occupation by evading airstrikes. It has become obvious that the larger powers have no real answer on how to battle effectively against underground forces, other then planting explosives at the entry or exit points or using aerial bombers to drop deep penetrating missiles into tunnel locations. This, however, is largely ineffective since many underground structures have detours that lead to multiple entry and exit points, making the destruction of them more complicated. It also doesn’t help that the sections which have been demolished by explosives are easily repairable. Another issue surrounding the search and destroy aspect of combating this underground system is that soldiers are often unable to determine whether or not the tunnels are booby trapped. The use of vacuum bombs in Syria, which can devastate anyone hiding in tunnels, has still not eliminated the ISIS threat since a major issue with attacking tunnel locations is finding them in the first place.

This type of warfare has been effective for centuries; what ISIS and Hamas is doing is bringing notice to it. And now Ukrainian insurgents will likely follow suit. Most nations in the Middle East and around the world for that matter already have these underground structures in place and will only be emboldened

against stronger nations the longer a small number of militants—relatively speaking—are able to survive by simply building underground fortifications. Israel and the US are working on technology that will allow them to detect underground tunnels, and if they are successful, we may see an end to the prolonged conflict in the Middle East and in Eastern Europe since such technology would also allow Russia to put a final end to Ukrainian insurgency. But if this is not the case, then we can expect that everyone there will attempt to pursue self determination without regard for another country's superior air power. The technology used to detect underground tunnels involve the use of seismic or gravity detectors. Seismic detectors are able to measure the vibrations as they pass objects beneath the surface of the earth, and if able to find a common anomaly that would identify the existence of a tunnel, those detectors could be effective. However, there would still need to be intelligence that pinpoints the general area of where a tunnel may exist. Gravity detectors like gravimeters are able to detect changes in the Earth's gravitational field based on the density beneath the surface. The presence of a void underground would reduce the gravitation force and would thus show up accordingly on the gravimeter. Another method is measuring the voltage of an electrical current, which would move at a lower voltage inside a void. Ground Penetrating radar(GPR) is another device used. to detect tunnels. GPR uses pulses of radio frequency energy to see underground. The distances detected underground however is limited, since it maxes around a depth of 50 ft. Tunnels have been dug by drug smugglers and militants as far as 100 ft beneath the surface. The use of bunker busters(aerial bombers employed by the US against ISIS) which can penetrate hundreds of feet of both earth and concrete, is still challenged by the possible extensiveness of the tunnels. Some tunnels have multiple detours that allow for escape and reconstruction of damaged sections. Drug smugglers now present a much higher risk in terms national security, since a tunnel system is both a defensive and offensive weapon—-irrespective of its use in drag smuggling activities. The arrest of two Houthi militants at the US/ Mexican border in 2021 raises the question of vulnerability, since one can posit that infiltration of Latin America by radical militants puts the US at risk of not only the implication of undetected drugs coming into the country, but also the implication surrounding the likelihood of a militant attack or ambush initiated from an underground tunnel originating from Mexico. The tunnel entries built by Hamas and ISIS are about 1 meter wide and go as deep as 100 ft beneath the surface. Pneumatic jackhammers are often used to dig out the tunnels and workers cover about two to three meters a day using them. Militants usually employ skilled workers to do the job. These workers normally have some knowledge of the engineering and geological aspects that go into constructing a tunnel. The tunnels are often dug from the inside of a shelter or home, which provides operatives with more stealth. ISIS militants who have escaped enemy fire, often seek refuge in nearby villages and pay residents there to help them construct tunnels. There are some hazards associated with the initial constructing process, such as cave-ins and collapses. It's common for workers to perish during

the excavation process, and collapses usually result from not waiting long enough after a torrential rainstorm to resume tunnel construction. As a result, soil erosion, which often compromises the landscape, puts workers underground at risk of being trapped after the collapse. Casualties have ironically allowed Hamas and ISIS to improvise on the underground construction process and gain a greater understanding of it altogether. Hamas has in turn managed to equip their tunnel system with electricity, concrete walls and ceiling, and is able to conduct communications using landlines, making it all the more difficult to detect their position. Ukrainian militias had success using landlines during the war in Donbas, keeping Russian drones from detecting their positions. This type of technical knowledge developed by mid-east insurgencies could be of advantage to Ukrainian insurgents and it is predictable that they may establish a channel of communication with militants in the middle east in order to gain more technical expertise on tunnel construction. Hamas has been able to smuggle concrete into Gaza and has used it to fortify their tunnel system. Hamas has stated that keeping the width of the tunnels thin(roughly 3ft), while digging out the tunnels so that the ceiling is arched reduces the chances of collapse. After excavation, the tunnels are stabilized with with 12-18 inch wide concrete arches, spanning roughly 3ft wide, and laid to sit atop 2 roughly 5ft high rectangular concrete slabs—one concrete slab holds up one end of the arch, while the other concrete slab holds up the other end of the arch. The tunnel diggers likely set each concrete arch and slabs as they go digging out the tunnel, making sure to remain under the arch as they continue digging, in order to mitigate the chances of being caught directly under soil and rock in the event of a potential collapse. The cement arch would provide stability and safety while excavating. The slabs on the side could protect against cave-ins. From videos showing Hamas tunnels, the part of the arch that sits atop the slabs is engineered and cut in such a way that the slabs on the walls of the tunnel are stabilized by the arch, preventing the chances of a cave in. Cave-ins are usually a very common accident on sand beaches during the vertical excavation process by beachgoers. The way to reduce this risk on sandy beaches is by applying wooden boards and other supports to the walls of the vertical excavation. Moreover, Hamas has developed rocket-making factories underground and they also have a deep-sea diving team that collects old shell fragments which are then made into warheads. Ukraine is said to have a secret underground factory where they build long-range rockets called grim missiles that can strike a target at distance over 200 kilometers.

ISIS, on the other hand, has a less featured system, but has learned over the years how to survive direct air assaults by hiding underground. It's likely that ISIS will build their tunnels based on the proximity of gas fieid locations. Many of the recent ambush attacks by ISIS against Syria have occurred near oil and gas fields. Oil and gas are both important elements of warfare, as they allow militants to maintain electrical, logistical, and communication channels. Much like Hamas has developed underground tunnels into Egypt for the purpose of smuggling. Ukrainian insurgents make seek

to develop a similar underground network into Poland for the same reason.

The biggest threat to any underground structure is heavy rain. In most tunnel collapses, heavy rain is often the main cause. Geologically speaking, rain effects on underground tunnels are often deterred by things such as concrete, asphalt or mulch which shields the soil from the effects of heavy rain or wind. In tunnel collapses, after the rain water hits the soil, it eventually infiltrates its way to the tunnels surrounding rock, weakening it though erosion. Water gets into cracks and joints, eventually causing the rocks to break open and split apart. At the moment. one can presume that precipitation is perhaps the greatest threat to underground tunnels. This in itself is a form of intelligence since it's likely that, because of this, militants will not shelter or construct underground during days of heavy rain. They may also, as a way to improvise, start constructing tunnel paths directly underneath surface paths formed with concrete or asphalt, i. e. city streets. This would lessen the effect of heavy rain on tunnel stability. However, the lack of arable land and prevalence of prolonged droughts in the middle east still allows for uninterrupted construction of sustainable tunnels there. This allows us to comprehend the notion that underground structures would be more operational or populated during seasons of drought as opposed to seasons of precipitation. It's likely that militants in the middle east have already planned in advance for climate factors. The approach to this field of conflict should be applied with some discrimination since factors like 'What the tunnels are being used for' need to be taken into consideration. Smuggling purposes would not warrant a counter~terrorism search and destroy operation since civilians are often employed and in many cases forced into transporting cargo to and from. If the tunnels are used for both, then it's all the more difficult to discriminate accordingly. Ideas have been presented which propose that soldiers infiltrate on foot into the actual tunnels and conduct operations from there. The challenges to this idea is that signals are often weaker or disabled below the surface, making it difficult to maintain good communications. Another issue is the question of soldiers having the necessary oxygen to carry out prolonged. subterranean missions. Beneath the surface, oxygen levels are usually lower, which puts soldiers at risk and endangers the mission. There is also the potential of carbon monoxide poisoning should soldiers be exposed to heavy smoke. Gas mask and other oxygen-storing equipment would be ineffective in protecting personnel against a carbon monoxide build-up within such an enclosed space. Ideally being able to detect and display tunnels on above surface radar makes for a more astute counter tunnel strategy since personnel would be less required to enter the underground fortification. They can simply wait for operatives to exit the underground structure before apprehending the situation. This makes it easier to discriminate exactly who goes into and out of the tunnels.

The above surface structures provide some protection to underground tunnels. Concrete and asphalt reduce the effects of heavy rain on the soil and averts the possibility of rock erosion

beneath the surface, which is normally a factor that causes many underground structures to collapse. This makes concrete the number one area of interest in developing an underground tunnel. If the workers are apprehending the effects of precipitation, then it's likely that they have improvised by routing tunnels to follow an alignment with the above surface concrete. If that is not the case, then they would have improvised to only construct or inhabit tunnels during dry seasons, and reduce operations there during wet seasons. Gaza militants fortify their tunnels with concrete surroundings, however due to creep (which happens to concrete under sustained load), concrete can easily collapse underground. Heavy soil and rain infiltration into underground rocks cause rocks to break, losing their ability to support the surrounding soil. The wet heavier soil then places more pressure on the underground tunnels, eventually causing them to collapse. There is a technique called rock bolting, which helps stabilize a tunnel system and is commonly used in tunnel construction. Rock bolts are simply long anchor bolts that are drilled into the ceiling of a tunnel in order to keep stability and prevent collapse from sustained load. Rock bolts are usually used in tandem with wire mesh to further reduce the risk of collapse.

Compared to other places, the Middle East presents less risk of tunnel collapse, due to the prevalence of droughts. Underground tunneling would be much more hazardous in tropical climates where it rains regularly, making the construction of underground tunnels aligned to the above ground concrete much more imperative. Paved roadways in urban areas provide a security aspect for tunnelers and a security risk for cities, should militants apply this type of warfare.

Mitigating the chances of being in the tunnel during a collapse would come with keeping a close eye on climate factors like precipitation, which is a primary cause of tunnel collapses. Making it a point to avoid tunnel excursion during times of heavy rainfall increases the likelihood of survival and reduces the risk of collapse while being present in the tunnel. Another issue is the possibility of carbon monoxide poisoning should a fire break out in the tunnel. The protective masks don"t usually protect against smoke. Ethanol vapor inhalation, however, could provide some protection against carbon monoxide exposure. In a study involving rats, ethanol intoxication was found to have a protective effect against carbon monoxide poisoning. This idea can be applied underground if the ethanol, which is a flammable agent, is sealed safely away from any possible contact with incendiary materials or ignition factors. Flammable materials are recommended to be stored in areas where there is strong ventilation. Underground structures, however, usually lack in this regard. The only workaround is for operatives to enter underground tunnels with alcohol in their system. The drawback of this is that the alcohol would contribute to reductions in judgment and reaction time in the event of a serious emergency. This is not the ideal state for anyone to be in during a risky mission, but it's the only way to safely make use of alcohol's protective effect against carbon monoxide poisoning in a poorly ventilated enclosed space. This also offers the idea that a trade off may be necessary, giving up some reaction time and judgment in exchange for extended time in the tunnels. Since alcohol correlates with a higher serum

potassium, one can hypothesize that the higher serum potassium level in the body is what is exerting the protective effect against carbon monoxide poisoning. I would go as far as hypothesizing that higher levels of potassium in the body reduces the body's need for oxygen, that infact the higher the potassium concentration in someone's system may cause oxygen itself to become more toxic. If this is true, this could be a breakthrough allowing people to survive longer in tunnels. In any regard, certainly during the breaching process, ethanol vapors could be applied to breathing apparatuses. The importance of a workaround is mediated by the fact that personnel would be able to stay underground mach longer.

In the present day, the Middle East is perhaps the greatest example of how effective tunnels are against urban defenses. Beginning in late 2013, ISIS, using subterranean warfare, was able to lay siege and occupy large swaths of territory in Iraq and Syria before eventual US intervention in Iraq in 2014 and Russian intervention in Syria in 2015. Even after encountering numerous aerial bombardments by US and Russian Air Forces in Iraq and Syria respectively, ISIS has still managed to survive with the use of tunnels, even launching successful ambushes against Syrian regime forces, a midst their dwindling numbers, thus prolonging the conflict and effectuating an urgency for greater battlefield discipline. Back in 2016, during an Iraqi offensive to reclaim Mosul, ISIS was able to maintain a foothold on the city by developing a large network of tunnels there. The stealth that the tunnels provided allowed ISIS to hide from enemy forces. They were also able to identify the location of Iraqi and Kurdish forces with the use of drones. While hiding underground, ISIS was essentially able to use the drones to locate enemy positions, and then launch surprise attacks on them. Many of the armed forces around the world have recognized the threat and began making concessions to deal with the problem. Israel faces the greatest challenge of dealing with the threat of underground operations by enemy forces. Hezbollah and Hamas have both made use of tunnel warfare and at numerous junctures, successfully infiltrated Israeli territory. Israel has bolstered their defense in response and used technology over the years to locate a number of cross border tunnels. The dangers of kidnappings, planting explosives, hostage taking, and all-out sieges are posed by effective use of underground tunnels, all of which will likely occur in Ukraine as insurgents attempt to reclaim territories from Russian invaders. In the West, many underground structures have been built, but mostly for drug smuggling and immigration purposes. There is at least an example of a tunnel being built for a bank robbery, which ended up failing due the collapse as a result of heavy rainfall. Part of the tunnel likely aligned with surface terrain comprised of dirt. When it rained, the water likely penetrated the soil and eroded the surrounding rock of the tunnel, causing it to collapse. It's probable in the future that attack tunnels will be built to align with surface concrete areas to reduce the risk of collapse from heavy rainfall.

Airstrikes and rocket launches are the number one cause of civilian casualties during military conflict. Major powers like the US, Russia, and Israel have extensive anti-missile and anti-aircraft

systems to keep their populations safe. Russia's system is called the s-400. The US has what is called the Patriot missile system. And Israel has the famous Iron Dome system that has been a proven resource in shooting down thousands of rockets fired from Gaza and thus saving thousands of Israeli civilian lives. Ukraine, due to Russia's assault on the country with numerous airstrikes and rocket launches, will be forced to come up with a plan to develop its own missile defense system if they plan to recapture territories seized by Russia and the separatists in eastern and southern Ukraine. Ukraine will likely pursue a strategy that will harness the power of anti-aircraft and anti-missile, as well as evasive tactics such as subterranean warfare. If the United States plans to arm the Ukrainian military for an indefinite period of time without getting involved militarily in the conflict, they will have to become instrumental in facilitating the development of an underground weapons smuggling network, at least until Ukrainian air defense are adequate enough to shoot down Russian rockets and keep them from destroying the depots that store western weapons. Much in the way that Hamas is able to smuggle weapons underground via Egypt, Ukraine will likely need a similar underground apparatus to smuggle in western weapons via Poland.

Today's anti-aircraft and anti-missile systems use a tracking radar to intercept targets and are launched from missile batteries stationed on the ground. There are basically five components to the battery. The first is the actual missile. Then there is the launcher which holds the missile, aims it at the target and launches it. Also included is a radar antenna which detects incoming rockets, aircraft or missiles. All of this is controlled via a control center, usually situated inside of an equipment truck. There, the computers with the radar interface and consoles are manned by operators. Another component of the system is a power plant truck containing at least 2 150-kw generators responsible for providing power to the control center's radar and computer equipment. The anti-aircraft and anti-missile system differs from portable shoulder-fired missile launchers, in that the anti-aircraft and anti-missile systems use ground based radar to track the incoming missile and aircraft targets. The portable shoulder-fired missile launchers use infrared homing to track its targets. However, this method is easily evaded by aircraft that drop flares, which cause the infrared seeker to go off course and instead track the heat from the flares as opposed to the aircraft exhaust. When it comes to ground based radar missile systems, the radar can lock onto an incoming missile 50 miles away, before it's ever visible to the human eye from the ground. Anti-aircraft and anti-missile systems have been upgraded over the years to detect other forms of aerial threats like ballistic missiles. They have also been developed with onboard radar systems that increase the ability of the missile to track its target. Because radar can be jammed with radio frequency signals, missiles with an onboard battery-powered radar can be programmed to switch to infrared homing in the event of its radar being jammed. Modern missile can fly at supersonic speeds. Equipped with frag warhead that explodes on impact, the 17 ft long missiles also carry a large fragmentation bomb with a proximity fuse that is set to detonate when in a certain

range of the target aircraft or missile. The fragmentation bomb is the main component of Israel's Iron Dome system, allowing the IDF to stop Gaza missile in flight by firing missiles that explode in close proximity to the Gaza rockets, causing them to be destroyed in flight or knocked off their course. The new onboard radar transmitters and guidance systems built into the missiles allow them to make contact with the target before exploding, which destroys the target completely. The missile launchers, which are mounted on a truck for transport, can hold somewhere between 4 and 16 missiles. For example, a launcher in the US Patriot missile system has 4 launch canisters that hold 4 missiles each. The launcher is usually powered by the electric power plant vehicle that carries 2 150 kw generators. Israel's Iron Dome system has about 3 to 4 launchers, with each able to hold 20 Tamir interceptor missiles. Russia's s-400 system launcher has 4 canisters, with each able to hold 3 short range missiles. Typically around 90 soldiers are required to operate a missile defense battery, and operators must be present in the truck housing the radar interface and computer systems that controls and guides the missile system. The operators have access to every target picked up by the radar and sensors, and can choose to operate the system manually or let it run automatically. They are also responsible for communicating with the regional command center. The radar that is used to detect incoming targets can also gauge its trajectory, height, and speed. Once the radar, after scanning the skies, identifies the target as hostile and illuminates it, the missiles launched can then track the target, and the operators can properly aim the missile at the incoming aircraft or missile by calculating the intercept point, which is usually calculated based on the target's previous flight path indicated on the radar. The missile usually has an antenna on the nose which can provide further information on the incoming missile while in flight heading in the direction of the incoming missile. The information received by the antenna is then transmitted back to the command booth, where operators then use the information to recalculate the intercept point, adjust the guidance and send the guidance commands back to the missile which will then adjust the course of the missile and bring it closer to the target. Other interceptor missiles have its own radar and computer systems built within it, allowing the missile to perform all the necessary calculations and guidance on its own. The speed of these missiles leave little margin for error. Also, the radar's software has to be optimized for detecting certain aerial objects, whether they be ballistic missiles, rockets/mortars, or aircraft/fighter jets. Algorithms are also applied to radar systems, which allows them to detect whether or not an aerial object is friendly or unfriendly. As of August 1st 2022, Russia has encountered a fierce Ukrainian counteroffensive powered by US HIMARS rockets. A number of these rockets have been able to evade Russia's air defense systems and some experts believe that Russia doesn't have the software to distinguish HIMARS rockets from grad rockets on its radar. This leaves Russia with a dilemma. Thus Ukraine, along with HIMARS rockets, can simply fire grad rockets from time to time and force Russia to fire more of their expensive air to air missiles that they would rather use against the HIMARS rockets. This will eventually

drain Russia's supplies as they try to develop software for the radar that would allow it to distinguish HIMARS rockets from grad rockets.

A new development in anti-missile systems will involve the same technology that powers self-driving cars. Whereas cameras/radars/sensors built into self-driving vehicles are used to help the car sense and navigate around people and other objects, those same cameras/radars/sensors built onto missiles will help missiles more easily ram into and strike incoming hostile aerial targets. Autonomous vehicles, also known as self-driving cars, uses cameras, sensors, and radars to track its own movements as well as the position and movements of surrounding objects and people so that the self-driving car can properly navigate without ramming into nearby people or objects. The major components of these autonomous vehicles are liDar, radar, and motion/object detection cameras. The radar used in self-driving vehicles comprises 2 types: Impulse and Frequency Modulated Continuous Wave(FMCW). The development of autonomous vehicles has been fostered by a great deal of ingenuity among some of the best technicians in the world, allowing the auto industry to evolve from human-controlled vehicles into an automated self-controlled ones. There is a huge race within the automobile industry to bring about the most efficient system of self-driving cars to the market. This task involves extensive research in sensor technology, motion detection, coding, AI, and radar systems. Self-driving cars rely on radar, lIdar, and ultrasonic. These sensors allow the vehicle to operate without the guidance of a human and gives the vehicle the ability to identify and avoid colliding with impediments, objects and pedestrians in the immediate environment. This same technology used in rockets could be used for the exact opposite purpose—colliding with and destroying any objects or impediments considered a hostile target. The technology behind self driving cars used in missile development will heighten the accuracy of missile strikes and anti-missile defense since object detection technology would have programs that would let the rocket maneuver towards the target without the need for the probability calculations used on current missile systems. Hypothetically, the bounding box used to identify a target object could be set to locate the angle point between the two missiles, allowing the interceptor missile to head straight for the angle point to meet and destroy the target missile or aircraft. This prospect would require advances in motion forecasting from liDar technology. Much of today's missile systems rely on calculating and predicting the trajectory of the target and locating the intercept point, but sometimes the prediction is wrong. Self-driving technology used in missile development greatly increases the likelihood that a missile will find its target. However, there also the possibility that hostile missiles with self-driving technology could be built to detect and evade incoming fire much in the way self-driving cars are made to evade people and things in the environment. Furthermore, the use of cameras as well as object and motion detection on missile systems will require quantum computing due to the hyper-sonic speeds at which missiles travel, making it to where detection and automated maneuvers will only have milliseconds to execute.

Ukrainian subterranean warfare tactics and possible new anti-missile technology using the same technology of self-driving cars.

Missiles are maneuvered using an exhaust nozzle that can be swiveled from side to side. When the nozzle remains steady in the middle, the thrust remains along the center line of the missile, keeping the rocket on a straight path. When the nozzle is swiveled to the left the thrust line becomes inclined to the center line of the missile, creating an angle called the gimbal angle. Since the trust is no longer passing thru the center line of the missile in this case, a torque is generated and causes the nose of the rocket to turn left. This is also what happens analogously when the nozzle is swiveled to the right, causing the nose of the missile to turn right. With self driving technology applied to missile systems, the nozzle can be automated to keep the missile in the position which keeps the onboard camera's object detection indicator fixated on the target. In self driving technology, the sensors are able to identify an object via a Raspberry Pi board attached with a pi camera module as well as an ultrasonic sensor responsible for data collection. A python program is then run on the Raspberry Pi, capturing the images from the pi camera and detecting the objects in it such as traffic signals(red or green light) and driving lanes. The ultrasonic sensors detect other obstacles in the path of the car. All the frames are cropped and modified into a numpy array. The images become properly labeled and the data is then put into a npz file before being generated onto an xml file, which would be loaded from the Raspberry pi once the car is started into self-driving mode, allowing the car to detect objects based on the trained data. Thus when the car is put in motion, essentially the onboard camera begins capturing frames from the streaming video and then transmits them to the Raspberry Pi controller where the algorithm is able to identify the object and respond accordingly. For traffic light detection, the algorithm can detect whether the color is red or green and initialize the vehicle to stop at the light if its red and begin driving once the light turns green. Much of this technology in terms of simple code is readily available for numerous devices. Webcams on laptops can be turned into motion and object detection devices with simple html code, giving an intermediate user basic insight into the algorithms for motion and object detection. It is likely that missile detection would be developed using the Haar feature-based cascade classifier methodology that was explained in a paper written by Paul Voila and Michael Jones in 2001. This methodology is a form of machine learning in which a cascade function, or classifier, is developed by extracting features from positive and negative images. For instance, for face detection, it takes both a decent number of positive images which contain actual faces and a decent number of negative images which are images that would not have faces, in order to develop an algorithm for being able to detect faces. For better accuracy, it often takes hundreds to thousands of positive and negative images as well as strong computing power. The next step is extracting features from the images, and this is done with cascading windows called haar filters which contain both black and white rectangles placed over different parts of the image. The features extracted are calculated by subtracting the sum of the pixels under the white portion of the haar filter from the sum of the pixels under the black portion of the haar filter. This process identifies aspects of the

image in relation to other parts of the image, i.e. for example if the region of the eyes is normally darker than the nose and cheek areas. Or if the eye region is darker than the bridge of the nose. This data helps the algorithm distinguish between and classify faces and non-faces. This process is what is called training the images and once complete, the vector data is generated onto an xml file. This training process can be done with any objects, including rockets and aircraft. And much in the way self driving cars use all these features to make itself run, likewise, on a missile, a Raspberry Pi board could be attached with a pi camera module and an ultrasonic sensor for collecting input data. Positive images of any target missile, along with negatives images that don't contain the target missile can be trained, with the data containing the extracted features generated onto an xml file. An example would be Ukraine taking hundreds of images of the Russian kh-22 missile that struck the Kredmash factory and adjacent Amstor mall back in June and training both the positive and negative images so that a kh-22 missile could be detected by the onboard camera of the interceptor missile. Whenever a kh-22 missile would be fired, the anti-missile system radar would detect the incoming missile and fire its own missile to intercept the target. The interceptor missile could theoretically have onboard a raspberry Pi controller with the xml file pretrained to classify the target missile—a kh-22 missile in this case. In flight, the algorithm would be able to identify the kh-22 missile, while the lIdar and radar system built into the missile would determine the range. The cameras on the missile would locate the kh-22 and track it with the bounding box, with the missile nozzle automatically programmed to swivel accordingly in a manner that directs its path towards the target, possibly by being set to maneuver in a way that keeps the bounding box set in a static position. Another possibility is technology where an algorithm would enable the onboard camera to detect the angle point between the interceptor missile and the trajectory of the target missile, allowing the interceptor missile to meet the target at that point and destroy it. This will require advances in liDar technology and its motion forecasting abilities.

Open CV is a popular cross-platform library that allows programmers to train their own classifiers for any object. Ukrainian researchers have likely already developed pre-trained classifiers generated as xml files to detect Russian missiles.

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A UKRAINIAN INSURGENCY WILL BE LONG AND BLOODY

Ukrainian subterranean warfare tactics and possible new anti-missile technology using the same technology of self-driving cars.

Thomas B. Pepinsky | 03.03.22 https://mwi.usma.edu/a-ukrainian-insurgency-will-be-long-and-bloody/ (paraphrased heavily)

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Implementation of Driverless Car Using Haar Cascade Algorithm

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